

photographs of objects in their natural surroundings. The lantern slides sent by Messrs. Sanders and Crowhurst are from photographs of birds, nests, eggs and young and other living animals taken by Mr. Oliver G. Pike. To lecturers on natural history such true pictures of living creatures must be invaluable, and no better source of encouragement to study nature could be desired. By the side of such beautiful photographic pictures as are now available for projection upon a screen or for the illustration of books, the drawings which did duty in natural history instruction seem but a vain show. Messrs. Sanders and Crowhurst send us with their slides an ingenious arrangement for viewing lantern slides under a low magnifying power. The arrangement, though simple, is very effective, and a pleasant half hour can be passed by using it to look at lantern slides.

THE additions to the Zoological Society's Gardens during the past week include a Greater Vasa Parrot (*Coracopsis vasa*) from Madagascar, presented by Lady Amherst of Hackney; a Black-footed Penguin (*Spheniscus demersus*) from South Africa, presented by Lieut. F. J. Mosely; a Black-headed Gull (*Larus ridibundus*), European, presented by Miss M. Hall; a Bataleur Eagle (*Helotarsus ecaudatus*) from Lagos, presented by Mr. J. Peacock; two Yellow-cheeked Amazons (*Chrysotis autumnalis*) from Honduras, two Wall Creepers (*Tichodromus muraria*), European, deposited.

OUR ASTRONOMICAL COLUMN.

DISTURBANCE OF CORONA IN NEIGHBOURHOOD OF PROMINENCES.—Prof. C. D. Perrine, who had charge of the expedition to Sumatra organised by the staff of the Lick Observatory to observe the total eclipse of the sun on May 18, 1901, gives in his report a preliminary description of the results obtained in the *Astrophysical Journal*, vol. xiv. pp. 349-359. From a short examination of the photographs of the corona obtained with the forty-foot and Floyd telescopes (which are stated to show the details of the inner corona very perfectly in spite of the presence of clouds during the exposure), there is distinct evidence of disturbances in certain areas of the coronal structure. Especially noticeable is a conspicuous series of coronal hoods surrounding a prominence in position angle 115° , and also an unusual appearance in the north-east quadrant of the corona. This latter is near position angle 65° . Close to this point on the limb there is a small compact prominence, surrounding which the disturbed area has a form roughly resembling an inverted cone of large angle. The apex of this area is not visible, appearing to lie below the chromospheric layer showing at the limb. From the apparent position of the apex, a number of irregular streamers and masses of matter radiate as if propelled by some explosive force. A long thread-like prominence to the south of this point appears to originate from the same source. Above and around this region the corona is composed of broken irregular masses, very similar to those depicted on the photographs of the Orion and other nebulae.

A NEW SOLAR THEORY.¹

IT is a remarkable fact that in the numerous theories which have been propounded in explanation of the periodic changes of the solar phenomena no account has yet been taken of so important an element as the light- and heat-absorbing envelope surrounding the photosphere. The attention which this so-called solar atmosphere has hitherto received, on the part even of our most eminent investigators, in connection with the economy of radiant energy on our luminary, is utterly disproportionate to the importance of the subject. In spite of the fact, which was first accurately established by Langley's observations and was afterwards confirmed by others, that the sun, if deprived suddenly of this protecting screen, would radiate into space as much as double its present amount of energy, solar

physicists failed to perceive that changes in the absorptive power of this envelope must entail consequences of the most far-reaching character with respect to the thermal conditions on and in the sun. That such changes—and these, too, of no inconsiderable magnitude—must inevitably occur is a conclusion which it is hardly possible to evade when it is remembered that the supreme control over the dispensation of solar energy depends entirely on a thin, shallow surface-layer, the matter of which is constantly tossed about by vehement eruptions and acted upon by a most complicated and powerful system of convection currents to and from the sun's centre.

The possibility of variations of the opacity of the solar atmosphere was, it is true, strongly urged, more than twenty years ago, by one of the greatest authorities on this question. Shortly after his well-known researches into the absorbing faculty of the solar envelope, Langley pointed out the decisive influence on the sun's radiation into space caused by changes in the transmissive power of its atmosphere. But his attention was at the time solely directed towards their probable effects on the temperature of our own planet. He found that an increase of absorption by as much as 25 per cent. would diminish the mean surface temperature of our globe by 100° F., whilst a like diminution in the solar envelope would produce a corresponding change in the opposite direction.

Now if the influence of a change in the absorptive power of the solar atmosphere is so enormous on a planet at a distance of almost a hundred millions of miles, of what inconceivable importance must it not be for the sun itself? Drawing the very natural inference that a deficit of outside radiation means a surplus of energies working upon the solar matter, and *vice versa*, we are forcibly led to conclude that even slight changes of opacity, such as would elude our most refined observations, are bound to greatly influence the state of thermal equilibrium on our luminary.

Hence, if changes in the absorptive power of the sun's atmosphere exist, as cannot but be the case, the question presents itself: What happens with those energies which, by a condensation of the solar envelope, are prevented from escaping into space? No doubt they are preserved to the sun, but in what form? Do they raise the temperature of the solar mass, or augment its store of potential energy, or have they a share in the generation of those marvellous dynamical displays which we perceive in periodic succession on the solar surface? Questions such as these must tend to convince the investigator that a research into the causes of the variability of the forces which we see acting on the sun, if not identical with, is at least closely akin to, the investigation of the origin and the physical properties of the sun's atmosphere. I shall endeavour, in these columns, to demonstrate the possibility of such changes in the density of the solar envelope as would lead to alterations of the thermal conditions of the sun's mass, and shall make an attempt to answer the question as to how far these changes must be conducive to variations in the dynamical phenomena at the sun's surface.

There is perfect unanimity amongst astronomers as regards the nature of the force which by a continuous generation of heat compensates for the loss of energy into space. Helmholtz's theory, which attributes this heat-generation to the progressive contraction of the solar mass as a consequence of gravitation, may be regarded as one of the most probable hypotheses ever propounded in the history of physical science. But this theory does not yet enable us to form an idea of the evolution of a celestial body. It explains the existence of a heat-generating force within the star's bulk, but it gives no answer to the question as to whether the loss of energy by radiation is exactly compensated for by the generation of energy through contraction, or whether the conditions of contraction peculiar to the sun may not perhaps produce more or less heat than is required for compensation. It is, indeed, inconceivable that the conditions of contraction can remain the same throughout the lifetime of a star. The spectroscope has revealed the fact that the photospheres of different stars exhibit widely different stages as regards temperature. There are doubtless suns hotter than ours, and others considerably cooler. And we may confidently assume that the various conditions of temperature now recognised in the different types of star-spectra represent the phases which successively appear in the evolution of each of these bodies from its origin as a far-extended nebula down to its complete obscuration. In the life of each of these stars there will be a period when its temperature is on the ascent, and when, consequently,

¹ Abstract of a paper in *Astr. Nachr.* (No. 3723-24): "Ueber eine neue Theorie zur Erklärung der Periodicität der solaren Erscheinungen."

the heat-generating effect of the contractile force exceeds the loss by outward radiation, as well as another period when the declining temperature of the star indicates an excess of the heat-dissipating over the heat-producing forces. Which of these conditions, at the present moment, prevails on our sun can so far be only a matter of conjecture. In this respect, therefore, an assumption has to be made. The following inquiry applies to the case of a star on which the generation of energy by contraction falls short of the loss of energy by radiation. Whether the results of this investigation may be applied to the case of our sun must, then, depend on the further question whether the sun really belongs to those stars the temperature of which is declining. So far as I know, this latter opinion is at present held by the great majority of astrophysicists.

If on a star the loss of energy exceeds the production, the kinetic energy of its molecules, and consequently its absolute temperature, must decrease. Hence if the temperature of a layer, a_n , at a certain distance, ρ_n , from the centre was T_1 at the epoch t_1 , it will be T_2 at a later epoch t_2 , where $T_2 < T_1$. Now let a_1 be the level of the photosphere—or the level of maximum incandescence, and therefore also of maximum radiation—at the epoch t_1 . In consequence of deficient contraction the temperature of this layer must decrease, and the materials composing it must cool down, so that, at the subsequent epoch t_2 , the level of maximum incandescence will have shifted towards a layer, a_2 , nearer to the star's centre, where the temperature is still sufficiently high to maintain the incandescent state of all the particles. The space between a_1 and a_2 will then be occupied by particles in a less luminous state which act as an absorbing screen on the radiation emanating from a_2 . Whatever fraction of the total radiation which originally left the photosphere at a_2 is thus stopped in its outward progress will be in part absorbed by, and in part reflected from, the intervening particles of the layer a_1a_2 , and there can be no doubt that some at least of this arrested energy will ultimately be thrown back to a_2 from which it started. The layer a_1a_2 must therefore act on the photospheric radiation in the same way as do our atmosphere and its clouds on the radiation from the soil. We are quite familiar with the fact that clear nights are, as a rule, cooler than cloudy ones, and we explain this phenomenon by the assumption that on clear nights radiation from the soil into space goes on more freely than when clouds offer an effective impediment to the dissipation of radiant energy.

We conclude, then, that the progressive cooling of the star leads to the formation of an absorbing envelope above its photosphere, by which the disproportion between the generation and loss of energy is reduced. But if, under the conditions at the epoch t_2 , the amount of energy actually radiated into space still exceeds what is produced by contraction, the photosphere will move to a_3 , still nearer to the centre, and the quantity of absorbing matter in the layer a_1a_2 will be further increased. Now although a_2 emits the same quantity of energy as did a_2 and a_1 at the former epochs, the total amount of radiation emerging into space must, at the epoch t_3 , be less than it was at t_2 and t_1 . Thus the opacity of the cooled atmosphere gradually increases as time goes on, and the total radiation of the star becomes less and less. Since no force is present to interfere with the cooling of the layers $a_1, a_2, \dots$, a moment t_n must eventually be reached at which the photosphere at a_n , through reflection from all the layers above it, receives back so much of its radiation that its total expenditure of energy is exactly counterbalanced by the energy contributed by the contractile forces.

This result appears to be of eminent importance. For it shows that even on a star with deficient contraction the exact compensation of the loss of energy may still be possible from a certain layer downwards. This state, so exceedingly important for the conservation of energy within the star, is brought about by the progressive cooling of its superficial layers, which thereby increase their power of absorption and thus offer a more and more effective check to the radiation from the incandescent layers below.

Here, now, we are confronted with a question which leads us at once to the principal object of this inquiry: Can the state of thermal equilibrium thus eventually attained by the layer a_n be permanent? The answer is clearly negative. For when a_n has arrived at this state, none of the layers $a_1, a_2, \dots, a_{n-1}$ outside a_n have reached the same condition. Their cooling is bound to go on, and consequently their ability to absorb and reflect the heat emanating from the layer a_n must still further increase even after the establishment of thermal equilibrium at a_n . But, owing

to this increasing amount of reflection towards it, the layer a_n will now dissipate even less energy than is required for the maintenance of thermal equilibrium, and therefore must become overheated. It thus comes to pass that, while the function of the absorbing envelope is that of reducing as much as possible the waste of energy from the photospheric layers, it is, by the very nature of this process, compelled to overdo its work, and to preserve finally too much energy within the star.

Now by this gradual overheating of the inner layers the vertical temperature-gradient must increase more and more, until it reaches a degree of steepness at which the permanence of a mechanical equilibrium becomes impossible. In such a case the overheated gaseous matter will force its way outwards and will break through the "cloak" of absorbing elements above it. But the overheated matter will not at once obey its molecular impulse to escape into higher levels. We must remember that there exists a powerful system of convection currents between the interior and the surface of the sun, and that the overheated particles may for some time be swept along the paths of these currents and may thus be forcibly detained in levels inconsistent with their increased temperature, so that their state of equilibrium is rendered unstable. This will produce a tension which increases in course of time until the upward tendency of the overheated particles becomes strong enough to overcome the resistance of the currents. At such a critical moment even a slight disturbance will be sufficient to induce the upward motion so long restrained, thus giving rise to a solar eruption. The cause of a solar outburst is therefore to be found in the temporary existence of an excessively great vertical temperature-gradient caused by progressive cooling of the outer atmospheric layers and the ensuing overheating of the inner photospheric layers.

From this exceedingly simple principle we are able to deduce an analytical demonstration of the periodicity of solar phenomena which explains all the characteristics of the sunspot curve hitherto observed. Obviously, the problem consists in demonstrating the changes in the amount of outward radiation which are caused, on the one hand, by the increase of absorptive power of the atmosphere in consequence of its progressive cooling, and, on the other, by the reduction of absorptive power of this same atmosphere in consequence of the "clarifying" action of eruptions which, by breaking through the "veil," diminish the number of cooled absorbing elements at the localities of eruption. I shall not enter upon this part of my investigation in the present note beyond stating that it is a simple application of Bouguer-Lambert's formula for the extinction of light and heat in an absorbing medium. The energy $\mathfrak{D}$ of the radiation leaving the upper limit of the atmosphere is found by the differential equation

$$\frac{d^2\mathfrak{D}}{dt^2} + a\frac{d\mathfrak{D}}{dt} - a\beta\mathfrak{D} = 0,$$

where t denotes the time reckoned from the moment when the photospheric layer a_n has attained its state of thermal equilibrium, and a and β represent constants, the former of which depends on the rate of cooling of the atmosphere, the latter on the action of the eruptions. The integral of this equation will thus give us the changes in the radiating power of the sun towards a point in the universe. Considering that the intensity of the dynamical phenomena at the solar surface must depend on the excess of energy preserved to the sun beyond what he requires for the maintenance of thermal equilibrium at a_n , we arrive at the following theoretical equation for the frequency of eruptions and spots:—

$$r = a \left[1 - e^{\lambda_1 t} + \frac{e^{\lambda_1 \rho} - 1}{1 - e^{\lambda_2 \rho}} (1 - e^{\lambda_2 t}) \right]$$

where ρ is the period and

$$\lambda_1 = -\frac{1}{2}a + \sqrt{\frac{1}{4}a^2 + a\beta}$$

$$\lambda_2 = -\frac{1}{2}a - \sqrt{\frac{1}{4}a^2 + a\beta}.$$

It is readily seen that r starts from zero at the moment $t=0$, and that it reverts to zero at the moment $t=\rho$. Between these two moments r attains a maximum, and we find the time when this occurs from the equation

$$e^{(\lambda_1 - \lambda_2)t_m} = \frac{\lambda_2}{\lambda_1} \frac{1 - e^{\lambda_1 \rho}}{1 - e^{\lambda_2 \rho}}.$$

Now it can be shown that the right-hand side of this equation is under all conditions $< e^{(\lambda_1 - \lambda_2) \frac{t}{2}}$, and this the more so the greater the difference between λ_1^2 and λ_2^2 . Hence we deduce $t_m < \frac{1}{2}p$; i.e. the ascent from zero to the maximum must take place in an interval of time shorter than half the period. This constitutes the first theoretical proof of the well-known property of the observed spot-curve that the ascent is steeper than the descent.

To give some idea of the accuracy with which the above theory

mical phenomena at the surface. Now these variations must react on the development of eruptions and spots. If the currents are weak—viz. if the transfer of heat from the interior to the surface is comparatively small—the cooling of the atmosphere must proceed rapidly, and hence the development of eruptions, which are a direct consequence of this process of cooling, must be energetic. At such times we have, therefore, to expect solar cycles with a powerful display of dynamical phenomena. If, on the other hand, the currents are intense—viz. if the heat-supply from the interior is vigorous—the rate of atmospheric

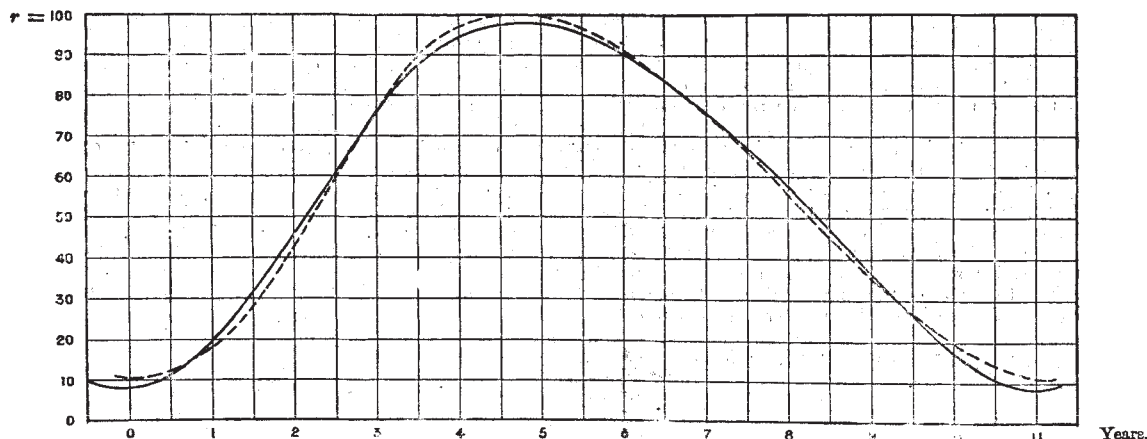


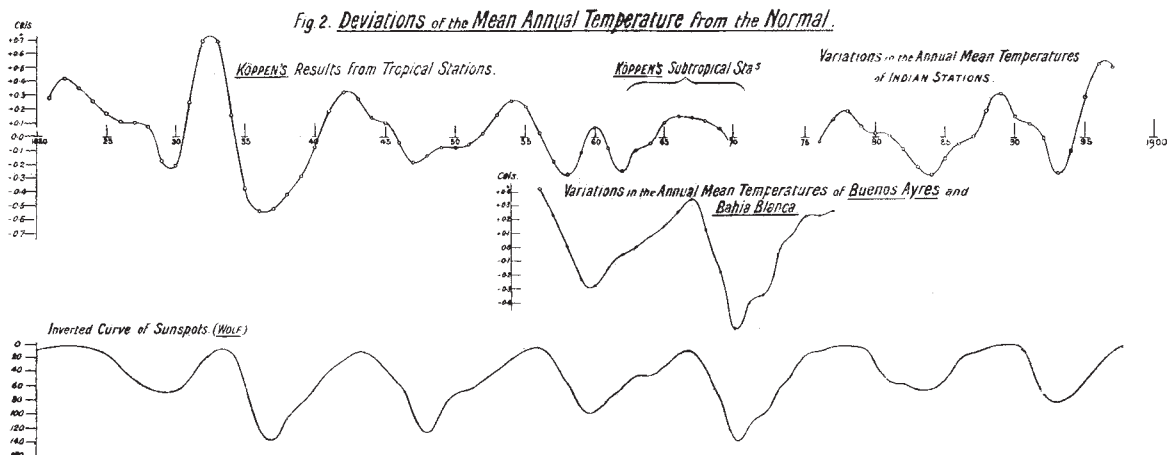
FIG. 1. — Theoretical curve of solar spots. Observed curve of solar spots (Spörer).

can be made to represent the observed facts, I subjoin a plate (Fig. 1) in which the spot-curve, resulting from theoretical considerations, is compared with Spörer's curve derived from observation. A full description of the method by which the theoretical curve has been obtained will be given in a paper shortly to be published as part of the first volume of the *Annals* of the Royal Observatory, Edinburgh.

The theory also accounts satisfactorily for the existence of a "great" period of solar phenomena. This greater cycle is brought about by the influence of the surface fluctuations of temperature described above on the intensity of the convection cur-

cooling will be small, and we have then to expect cycles with only a weak development of surface phenomena.

Since the quantity α depends on the rate of cooling of the atmospheric layers, it will attain high values at times when the spot-development is powerful, and *vice versa*. Now the greater α , the greater will be the difference between λ_1^2 and λ_2^2 , and, consequently, the earlier must the time of maximum, t_m , occur. Hence the position of the maximum in the spot period relatively to the preceding minimum must depend on the greater or less vigour of spot-development during the cycle, inasmuch as the time of maximum must be the more in advance of the centre



rents which regulate the interchange of heat between the interior and the surface. It is inconceivable that in a gaseous body like the sun, governed by a gigantic convection, changes of temperature of parts of its mass can be confined merely to the surface. Hence we must conclude that the distribution of temperature throughout a considerable part of the sun's bulk will be more or less affected by the fluctuations of temperature at the surface, and that consequently the intensity of the system of convection-currents, which depend on this distribution of temperature, must undergo variations similar to those exhibited by the dyna-

of the period the greater the display of the dynamical phenomena. This important conclusion, arrived at by purely theoretical considerations, is amply corroborated by the facts. I refer in this respect to a recent publication of Dr. W. Lockyer, in which this peculiar shift of the maximum is pointed out as a feature of the observed spot-curves.

The object of this brief abstract being merely an exposition of the main principles upon which I have ventured to build a new solar theory, I shall not enter upon its various applications to the phenomena connected with the periodic changes in the

display of forces at the sun's surface. In this respect the theory will be submitted to an exhaustive test in my paper in the *Annals*. In one important point it involves a radical deviation from the views hitherto held. So far investigators have almost unanimously adhered to the traditional view that an increase in the dynamical forces at the sun's surface indicates at the same time an augmentation of his light- and heat-radiation into the universe. A theory founded on this assumption would have to account, not only for the extra expenditure of force into space, but also for the simultaneous increased development of force in the sun. But in the theory here proposed the exactly opposite conclusion is arrived at. Here the forces which we see acting on the sun are called into existence by the accumulation of such parts of his radiating energy as have been prevented from being thrown off into the universe. Thus a surplus of energy working on the sun means a deficit of energy communicated to space.

It will be important, then, to ascertain how far this conclusion can be verified by observed facts. Modern researches seem, indeed, to corroborate this theoretical result. If the theory be true, the temperature of the solar layers inside the absorbing atmosphere should be higher at the maxima than at the minima of solar activity, while the temperature of a body in space, which receives its heat from the sun, should vary inversely. In proof of the first conclusion I may refer to Sir Norman Lockyer's results with regard to the be-

Behrens divides the bronzes into two principal groups—those rich in copper, containing from 1 to 25 per cent. of tin, and those rich in tin, containing more than 25 per cent. of tin. With the exception of the metals for mirrors (25 to 35 per cent. of tin), which appear homogeneous, Mr. Behrens says that in all bronzes a portion rich in copper or rich in tin may be detected, forming the fundamental mass, the former in alloys rich in copper, the latter in those rich in tin.

Charpy (*Metallographist*, vol. i. p. 193) divides them into those rich in copper, containing 100 to 73 per cent. of copper, and those rich in tin, which are again divided into four groups—0 to 3 per cent. of copper, in which tin crystallises in the matrix; 3 to 55 per cent. of copper, in which a compound of tin and copper crystallises out of the matrix; 55 to 65 per cent. of copper, which have a structure quite homogeneous and difficult to resolve; and 65 to 73 per cent. of copper, in which hard white grains crystallise in the higher eutectic.

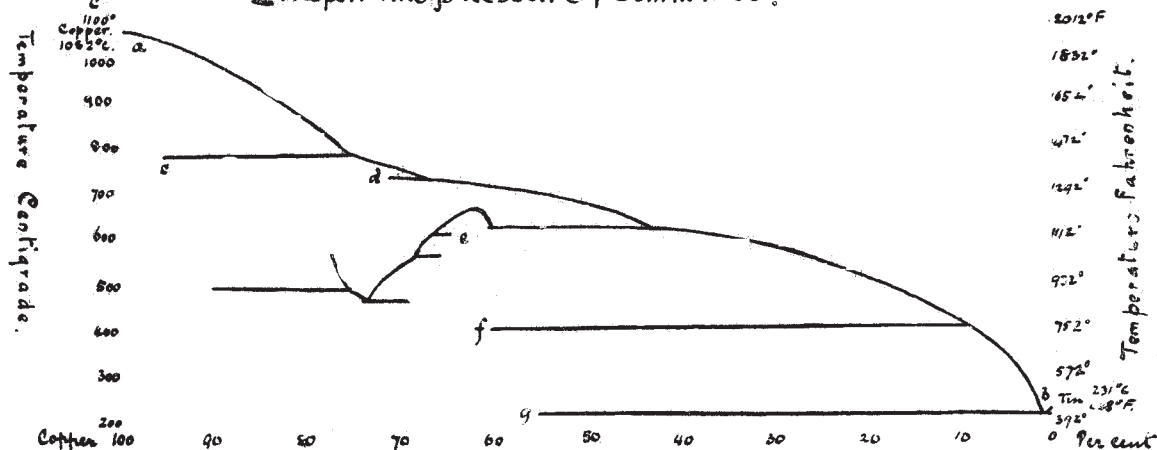
The curve of fusibility, as determined by Le Chatelier, is composed of three branches, forming by their intersections two points corresponding to alloys with 3 and 72 per cent. of copper.

0 to 3 per cent. of copper : straight : fall.
3 to 72 „ „ uniformly curved : rise.
72 to 100 „ „ almost straight : rise.

This curve and the results of Charpy (*Bull. Soc. d'Encouragement*, March, 1897) from microscopic analysis closely agree.

Fig. 1. Freezing-point Curve of Copper-Tin Alloys.

IV. Report Alloys Research Committee.



haviour of the lines widened in the spectra of sunspots, from which he infers that the matter composing the spots must be of higher temperature at the times of maxima. The second conclusion, on the other hand, is corroborated by all the more important researches which have recently been made regarding a connection between the changes of terrestrial temperature and solar activity. Of some of these I subjoin the main results in Fig. 2, which exhibits the observed changes in the mean annual temperature at tropical and subtropical stations and the corresponding variations of solar activity. It will be seen that for the whole period from 1821 until 1898 the temperature-curve follows most accurately the fluctuations of the inverted spot-curve, thus so far proving the validity of the second conclusion, that space receives less heat at the maxima than at the minima of solar activity.

J. HALM.

MICROSCOPICAL EXAMINATION OF ALLOYS OF COPPER AND TIN.¹

THE microstructure of the copper-tin alloys has been studied by Behrens, Charpy, Stead and others. Recently Messrs. Heycock and Neville (*Phil. Trans. Royal Society*, 1901; Glasgow meeting, British Association) have published several papers on the effect of quenching upon the microstructure.

¹ Abstract of a paper by Mr. William Campbell, Columbia University, New York, late of the Royal School of Mines, London. Read before the Institution of Mechanical Engineers on December 20, 1901.

If, however, we study the complete cooling curve of the copper-tin alloys, by Sir William Roberts-Austen (Fig. 1), the meaning of only a part of the curve will be found to have been explained by previous workers. The branches c, d, e and f remain unaccounted for.

The result of the microscopical study of these alloys is shortly as follows:—

0 to 1 per cent. Copper.—On the addition of even 0.1 per cent. of copper to tin, a new constituent surrounding the grains of tin can be seen. As the percentage of copper increases, the amount of enveloping material increases also, and the tin grains decrease in size and number until about 1 per cent. copper; they entirely disappear when the whole mass is composed of the first eutectic alloy. When these alloys are cast, the grains of tin are greatly reduced in size.

1 to 8 per cent. Copper.—When the copper is increased above 1 per cent., thin bright needles are seen, which increase in size and number and vary in their method of grouping until 8 per cent. of copper is reached. Their composition varies also, increasing from 33.5 per cent. Cu to 44 per cent. Cu, as was pointed out by Stead (*Journal of the Society of Chemical Industry*, June, 1897). Casting produces a network of fine crystallites, which tend to set along definite directions forming skeleton crystals. Cooling in the furnace greatly increases the size of the bright crystals and diminishes their number proportionately.

9 to 40 per cent. Copper.—With 9 per cent. Cu a new constituent crystallises out in forms similar in section to the crystals